AD-A058 271 WESTINGHOUSE ELECTRIC CORP PITTSBURGH PA ADVANCED ENE--ETC F/G 11/6
EVALUATION OF FRICTION PROPERTIES OF SHEET FORMING LUBRICANTS B--ETC(U)
MAY 78 F J GURNEY, A M ADAIR F33615-77-C-5099

UNCLASSIFIED AFML-TR-78-66 NL

1 OF 1
AD
A058271

END
DATE
FILMED
10-78
DDC

ADA058271

AFML-TR-78-66

(2) LEVEL II

EVALUATION OF FRICTION PROPERTIES OF SHEET FORMING LUBRICANTS BY TENSILE DRAWING AND BY RING COMPRESSION

AD No. ______
DDC FILE COPY

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED ENERGY SYSTEMS DIVISION
PITTSBURGH, PENNSYLVANIA 15236

MAY 1978

TECHNICAL REPORT AFML-TR-78-66
Summary Report for Period 1 May 1977 to 15 February 1978

AIR FORCE MATERIALS LABORATORY
AIR FORCE WRIGHT-AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

78 08 29 044

NOTICE

When government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Attwell M. Adair
ATTWELL M. ADAIR
Project Engineer
Metals Processing Group

FOR THE COMMANDER
Henry M. Graham
HENRY M. GRAHAM
Acting Chief, Processing and
High Temperature Materials Branch
Metals and Ceramics Division
Air Force Materials Laboratory

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

AIR FORCE/56780/10 August 1978 — 300

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

19

1. REPORT NUMBER

18 AFML-TR-78-66

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

6 EVALUATION OF FRICTION PROPERTIES OF SHEET FORMING LUBRICANTS BY TENSILE DRAWING AND BY RING COMPRESSION

5. TYPE OF REPORT & PERIOD COVERED

9 Final Technical Report

1 May 1977 ~~to~~ 15 Feb 1978

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

F. J. Gurney, Advanced Energy Systems Division
Westinghouse Electric Corporation, A. M. Adair,
Air Force Materials Laboratory (LLM)

8. CONTRACT OR GRANT NUMBER(s)

15 F33615-77-C-5099

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Westinghouse Electric Corporation
Advanced Energy Systems Division
Pittsburgh, PA 15236

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

16 73510817 17 Ø8

62102F

11. CONTROLLING OFFICE NAME AND ADDRESS

Air Force Materials Laboratory
Wright-Patterson AFB, OH 45433

12. REPORT DATE

11 May 1978

13. NUMBER OF PAGES

52

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 6Øp.

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

10 F. J. /Gurney Attwell M. /Adair

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Sheet forming
Lubricants
Metalworking
Ring test
Sheet friction

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Experimental and selected commercially available sheet forming lubricants were evaluated by two friction testing techniques; 1) strip-drawing with only elastic workpiece loads and 2) ring compression testing where plastic deformation of the workpiece occurred. Material and test variables examined were; 1) two workpiece materials Al-7075 and Ti-6Al-4V, 2) eight lubricants coatings, 3) three levels of hold-down pressure and deformation amount, 4) two die roughness conditions, 5) two drawing speeds and 6) two lubricant dryness conditions. The tests were performed at room temperature.

over

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

78 08 29 044

410 11Ø 1B

Results indicate that the lubricant dryness condition can be a significant factor in friction characteristics of the lubricant. Of the other variables, the lubricant type caused the most influence on the resultant friction characteristics. Quantitative ratings of each lubricants was obtained as a function of the test variables.

FOREWORD

This report was prepared by the Westinghouse Electric Corporation, Advanced Energy Systems Division, Pittsburgh, Pennsylvania, under USAF Contract No. F33615-77-C-5099. The project was initiated under Project No. 7351, "Metallic Materials", Task No. 735108, "Processing of Metals", and was administered under the direction of the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio, with Mr. A. M. Adair (AFML/LLM) as Project Engineer.

The work described in this report was carried out between 1 May 1977 and 15 February 1978. Technical support was provided by Westinghouse personnel, T. E. Jones, M. M. Myers, and R. A. Sweeney. Contributions by AFML personnel have been made by A. M. Adair and V. DePierre*. The various parts of this effort were compiled by Ms. Faye Hickman who also edited and typed the report.

This report was submitted by the author on 15 March 1978.

*Deceased

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION I

INTRODUCTION

Recent interest in improved production efficiency has resulted in consideration of computer-aided techniques for both design and manufacturing processes. In metalworking operations, a considerable portion of this interest is directed at sheet metal forming operations. The wide scale usage of sheet metal products in common items such as automobiles, stoves, furnaces, air conditioners, etc. attest to the large number of manufacturing organizations involved with this metalworking operation. The large majority of these applications is almost exclusively concerned with the ability to produce style effects without gross fracture and without aesthetically non-pleasing deformation effects such as non-uniform thinning, orange peeling, gathering or buckling. The material for the majority of these sheet metal forming processes is low alloy steels or low alloy aluminums, and the fabrication is almost exclusively conducted at room temperature.

This technology for the forming processes in these common usage items is mostly based on trial and error experiences of the individual sheet metal forming shops[1]. Because of this, the ability to transfer experience from one material to another within the same shop or from one shop to another for the same material often results in only limited success. The limited ability to transfer skill capability is the most serious deficiency with this "experience based" technology. The development of a sound scientific or engineering "knowledge base" for this technology is required to alleviate this deficiency.

Development of an engineering "knowledge base" for sheet forming processes is especially desirable for aerospace applications. In aerospace applications, component weight considerations frequently require the sheet product to have load transfer characteristics. Thus, reproducibility of service properties is critically important. The development of an engineering "knowledge base" for these forming processes is also an essential prerequisite to the establishment of a computer-aided and computer-controlled design and manufacturing process for sheet metal forming.

SECTION II

BACKGROUND AND APPROACH

One of the critical factors limiting the development of a "knowledge base" for sheet forming is the interface condition. The importance of the interface condition in sheet forming operations is well recognized[2-5] and has been shown by Goodwin[5] to be a factor which can influence the production of sound or fractured product (see Figure 1). However, despite its importance, the most generally accepted view of the effects of interface friction in these processes is that it can only be determined by trial and error techniques[6].

The use of bench-type evaluations of lubricants has generally been considered to be of only marginal usefulness[6]. It was only very recently that any success has been reported in quantifying the effects of friction in sheet forming operations. This initial effort by Ghosh[4] was directed primarily at materials and lubricants for use during room temperature stamping for automotive industry applications. The applicability of this initial effort to computer-aided processing is yet to be determined, but it is significant in that an attempt to quantify the role and effects of the interface condition is now underway.

The use of the ring compression test for evaluating friction under bulk forming operation is well documented in the literature[7-9]. This test has been shown to allow the simultaneous determination of friction stresses[7] of lubricants and the flow stress-deformation strain relationships[8] of materials under bulk deformation operations. Even though specific application of the ring test to sheet forming operations has been shown by Pope, Robins, and Berry[10], some question exists as to the validity of results from a bulk deformation operation when applied to sheet forming processes where lower tooling pressures frequently occur. Some of the concern of the various friction test methods is related to test techniques. Other concern is related to basic considerations of friction itself.

The basic aspect of evaluation of friction characteristics of lubricants on which this study is based is that quantitative characterization of the lubricant should be independent of the process system in which it is utilized. This idea of characterizing lubricants by their intrinsic shear resistance or shear strength is also argued by Schey[11] in comparison of friction results from ring compression testing and from twist compression testing. In this study, Schey points out that several lubricants are not only sensitive to pressure, but some are sensitive to the velocity at which shearing is accomplished. Schey suggests that at lower pressures, those at or below the compressive flow strength of the material, the shear restraint of the interface substance can be represented by an Amonton's Law relationship. This is represented by the following relation,

$$\tau = \mu P \qquad (1)$$

where τ is the shear restraint of the interface substance, μ is the assumed constant friction coefficient and P is the pressure applied normal to the surface. This concept of friction implies that the shear resistance of the interface substance is directly related to the applied pressure.

At higher pressure , those above the compressive flow strength of the material, the use of the interface shear factor concept has been argued to be a more realistic characterization of friction both by Schey[11] and also by Male and DePierre[12]. The interface shear factor concept of friction implies that the only meaningful values of frictional shear resistance are those in the range from zero frictional restraint up to the values of the shear strength of the workpiece material. Interface substances which have shear restraint greater than the shear strength of the workpiece material will not allow metal flow at the interface, rather sub-surface shearing of the workpiece occurs. This concept is illustrated by the following relation.

$$\tau = m \frac{\sigma}{\sqrt{3}} \tag{2}$$

where τ is the shear restraint of the interface substance $\sigma/\sqrt{3}$ is the von Mises shear strength of the material and m is the interface shear factor. The value of m can vary from 0 for a frictionless case to a value of 1 for the maximum meaningful friction case.

When fluid-like lubricants are employed in thickness sufficient to create a hydrodynamic film, they are sometimes considered as Newtonian fluids as suggested by Vdovin[13]. The frictional shear resistance of the film would then be related as shown below:

$$\tau = \eta \frac{\Delta\nu}{t} \tag{3}$$

where τ is the frictional shear resistance of the interface film, η is the viscosity of the interface film, $\Delta\nu$ is the velocity gradient within the film and t is the film thickness. The treatment of lubricants by this method gives an indication of the effects of pressure and temperature on the film shear strength through its direct relation to viscosity effect. For most materials, viscosity increases with increasing pressure and with decreasing temperature.

Consideration of these three views of friction illustrates some of the concern of lubricant evaluation and the applicability of the evaluation techniques to other conditions. The effort of this study will give attention to the application of the different views. The approach of this study was to examine the applicability of the interface shear approach to quantifying the interface condition in comparison with the coefficient of friction approach used by Ghosh[4]. The approach proposed for this task is to utilize the results from the ring compression test in combination with the results from a variable die-pressure strip-draw test.

SECTION III

EXPERIMENTAL PROGRAM

Material

Two sheet materials were investigated in this study, 7075 Al and Ti-6Al-4V. Both were procured in the form of 100 mil sheet. The chemical composition of these materials is given in Table 1.

Lubricants

The lubricants used in this evaluation were a combination of experimental and commercially available types. Since almost no information on quantitative evaluation of lubricants for sheet forming is available in the literature, the lubricants selected were deemed to be appropriate for the first round evaluation. Information from this first round evaluation would be used as the basis for classifying the lubricants and making the second round selection and evaluation. No attempt was made to select representative lubricants from the number of manufacturers, nor was any attempt made to evaluate the lubricants in their manufacturer's recommended use condition. Those lubricants used in this evaluation are given in Table 2.

Sheet Friction Test Equipment and Evaluation Procedures

The sliding friction resistance of the lubricants was evaluated through use of a specially constructed variable-die-pressure strip-drawing apparatus shown pictorially in Figure 2 and schematically in Figure 3.

The apparatus incorporates two particular features which allow data to be assimilated easily. The first of these features is the use of an air cylinder which together with bottled nitrogen gas and regulator can allow quick setting or quick change of the die hold-down pressures between 0 psi and 200 psi. The second feature is the dove-tailed die locking arrangement which allows quick interchange of the dies. The dies were made of H-12 tool steel and are shown in Figure 4 together with a sheet specimen used during testing. Two die surface conditions were used in the evaluation. One condition was as-ground with a roughness of approximately 32 RMS and the other was a lapped condition with a finish smoother than 1.0 micro-inch.

The sheet draw specimens, Figure 4, were produced with a strip area of width 1.0 inch and a length of 6.0 inches. The thickness surfaces of the specimen is the as-rolled thickness of the sheet. The lubricants were applied to the sheet specimens by either dipping or spraying, whichever was found to be more convenient. The lubricant was applied to attain a film thickness of approximately 0.005 inches. The lubricants were tested in two different conditions. One condition was the "just applied" condition where the test was performed within 30 seconds of application. The second condition was the dry condition where the lubricants were allowed to dry from 24 to 48 hours prior to testing.

Actual testing was accomplished with the strip-drawing apparatus fixed to a Tinius Olsen Testing Machine, Figure 5. Two cross-head speeds were utilized in the testing 1.5 ips and 15 ips. The tensile drawing load was monitored and recorded for each set of test conditions.

<u>Ring Test Equipment and Evaluation Procedure</u>

The ring compression test evaluation used in this program was performed on the 500 Ton Hydraulic Forge Press located at the Air Force Materials Laboratory. The basic characteristics of this test equipment and procedure has been described in the literature[7-9]. For these tests, an interchangeable die system was utilized which allowed the test series for each lubricant to be performed on dies which were free of contamination from previous lubricants. Each set of dies was lapped with 3 micron diamond polish prior to use in the ring forging evaluations.

The ring test specimens used were machined from the 100 mil sheet. Rings of 24:8:1 geometry (O. D., I. D., Thickness) were used where the ring thickness was the as-rolled sheet thickness. All machining and testing was done at room temperature in the as-received condition. The lubricants were applied to the rings by either spraying or dipping, whichever technique was found to be more convenient. An approximate lubricant thickness of 0.005 inches was applied to the rings and these coated rings were held at room temperature for 24 hours prior to testing for the cured condition but tested within 30 seconds of application for the "just applied" condition. Ring compression tests were performed at 10, 20 and 30 percent reduction in height. Analysis of the ring compression tests were accomplished as described in an earlier publication[9].

SECTION IV

RESULTS

The results from the variable-die-pressure drawing tests are presented in Table 3 and 4. The frictional restraint of each lubricant film is presented in terms of the friction ratio. This term is calculated as the ratio of the drawing stress to the clamping or hold-down stress. Both the initial and maximum value of this ratio were recorded. Trends in the values of the friction ratio are plotted in Figures 6-9. The results from the plastic ring compression test are presented in Table 5 with the results shown graphically in Figure 10.

Effects of Lubricant Curing Times

Results from lubricants which are tested within 30 seconds of application are shown in Figure 6 for the Al-7075 workpieces. Also shown on this figure in bold lines are three theoretical constant interface friction curves. The fit of the maximum friction ratios from the C-300 and DGF lubricants to the theoretical curve is seen to be almost exact over the range of hold-down pressures. The results from G-231 and G-203A indicate a somewhat close fit with the theoretical curves at hold-down pressures of 305 psi and 610 psi, but show significant deviation when the hold-down pressures is increased to 915 psi.

When the time period between application and testing of the lubricants is extended to 24 hours with all other parameters identical, the friction ratio results are significantly different. These results are shown in Figure 7. A relation yielding a constant value of friction ratio with increasing hold-down pressure indicates that the frictional restraint increases almost in proportion to the load normal to the lubricant film, i.e. a constant coefficient of friction. However, results from some of the lubricants show that the friction ratio increases with increasing hold-down pressure, indicating that the anti-friction characteristics of the lubricant itself are adversely affected by pressure.

The principal difference between the lubricants in the "just applied" condition and the dry condition is that a significant amount of the lubricant carrier is retained in the "just applied" condition. Almost none of this carrier remains after the coating has dried for 24 hours. For the majority of tests, the effect of this retained carrier was to reduce the friction condition. However, in one of the lubricants (Hydro), this retained carrier resulted in an increase in friction when tested on both aluminum and titanium workpiece material, Table 3.

Effects of High Hold-Down Pressures

The testing of three of the lubricants was continued to high hold-down pressures. Two of these lubricants were applied to the workpiece 24 hours prior to testing and one was applied just prior to testing. Results from these tests are given in Figure 8. The trends from the two lubricants which were allowed to cure before testing showed almost constant coefficient-of-friction type response for hold-down pressures as high as 2135 psi. The lack of significant variation between the initial and maximum values at any value of hold-down pressure indicates a very consistent response of the lubricants.

The results from the lubricant which was applied to the workpiece just prior to testing indicate that the low initial friction ratio is maintained up to the highest hold-down pressures tested, 2135 psi. A significant increase in the maximum value of the friction ratio begins to occur after hold-down pressures of 1220 psi indicating the breakdown of the favorable anti-friction characteristics as the drawing process continues. Galling between the aluminum workpiece and the tool steel die is associated with this breakdown.

Effect of Die Surface Finish

The effects of die finish were investigated for several lubricants applied to the Al-7075 workpieces. One die finish was 32 micro-inch RMS and the other was lapped smoother than 1 micro-inch. Except for the DGF lubricant, no significant differences in the two die finishes were noted. In the case of the DGF lubricant, the lapped finish resulted in significantly higher friction ratios, Table 3.

Effect of Drawing Speed

Drawing speed variations were investigated for three test series using lubricants applied to aluminum specimens only. Two draw speeds, 15 ips and 1.5 ips were investigated but no significant variations in friction resulted.

Effect of Workpiece Material

When tests were performed with lubricants in the dried condition, no effects of material were observed. When the "just applied" lubricants condition is compared, the results are less consistent, but generally slightly higher friction ratios resulted from tests on titanium specimens.

Comparison of Test Variables on Lubricant Response

A comparison of the effects of test variables is shown in Figure 9 for the DGF lubricant applied to 7075 Al. The results show an amount of scatter, with most variables but a clear effect of the retained carrier in reducing the sliding friction as the hold-down pressures are increased.

Interface Friction Factors from the Ring Compression Test

Since the initial testing of sheet forming lubricants were to be investigated for room temperature properties only, the ring forging tests were limited to the 7075 Al workpiece material. The higher flow stress of the Ti-6Al-4V and the thin ring specimens required forging loads which were too high to allow significant results to be obtained. The ring tests are presented in Table 5 and shown in Figure 10. These results show that the friction factors fall in a range between 0.10 and 0.22 for the majority of the lubricants tested for the cured condition. Results from the J-Wax and the MS-122 lubricants show definite trends with low values of friction factors.

SECTION V

DISCUSSION

The results of this study tend to show that none of three methods of characterizing lubricants outlined by the equations in Section II is completely suitable for evaluating frictional characteristics of lubricants for sheet drawing operations. Results from the variable die friction strip-draw test presented in Figure 6 show that a constant interface friction analysis is somewhat realistic if the lubricant contains some fluid components; this is particularly so for hold-down pressures between 300 psi and 600 psi. However, if testing is performed after these same lubricants have been cured to remove the fluids, then the constant coefficient of friction approach appears more realistic as can be seen in Figure 7. Considerable variation can occur for any lubricant depending on the conditions of the test as shown in Figure 9 for dry film graphite. The essential consideration of lubricants which is brought out by the data of Figures 6-9, is that the intrinsic properties of the lubricants are not completely characterized by the three basic equations discussed earlier. The frictional restraint offered by the lubricants must include a careful documentation of the manner of testing and the assumption included in the analysis.

When lubricant evaluation is performed for a specific process, certain simplifying assumptions are frequently made in the analysis. Generalization of the results based on those assumptions can cause significant difficulties when the same lubricants are used in different processes. An example of this condition can be made with the analysis of punch stretching by Gosh[(4)] in which it is carefully stated that a pressure dependence of friction coefficient generally occurs. In his analysis, however, Gosh reasons that the pressure changes experienced in punch stretching are small and that simplification of the analysis could be achieved if the friction coefficient were assumed constant and that Amonton's Law holds, Equation 1. Examination of the data presented in Figure 6 of this report shows that significant errors would result when Gosh's data or equations, based on no pressure effect, are used to predict friction when large pressure variations occur.

Further consideration must be given to the film breakdown condition which most frequently occurs when the lubricant is used at significantly higher deformation pressures or when it is used in sliding conditions where no replinishment is possible. The film breakdown condition is shown in Figure 6 to occur for the variable-die-pressure strip draw test with the lubricant in the "just applied" condition as the hold-down pressure is increased from 600 to 900 psi. A part of this effect is associated with the lubricant depletion as the sliding process occurs. It is interesting to note, however, that no film breakdown occurred when the "just applied" condition of these lubricants was evaluated by the ring forging test, even though significantly higher normal pressure were experienced, Figure 10 and Table 5. The reason for this effect is not readily apparent and perhaps should be investigated more thoroughly by testing at intermediate pressure conditions.

The condition of film breakdown occurrence because of continued sliding without lubricant replinishment is found to occur in a lubricant when very high hold-down pressures are used Figure 8. While the hold-down pressures used in these data are considerably in excess of those normally encountered in practical sheet forming operations, the results illustrate the greater stability and more consistent response when the lubricants are cured prior to use.

A direct comparison of the quantitative results from the two lubricant evaluation techniques cannot be made because of the large difference in the normal load each imposes on the lubricant film. Normal pressures from the strip drawing apparatus were in general varied between 305 psi and 915 psi. The normal pressures resultant from ring forging generally range between 40 ksi and 100 ksi. It is possible that the interface shear stress of the lubricant film is pressure dependent and the wide differences found in these tests are attributable to this effect. Because of the lack of data at intermediate pressures, when such a correlation was found it could not be established whether it was real or coincidental. Attempts to establish this pressure dependence with the results of these tests were abandoned because of this lack of intermediate pressure data.

Further comparison of the results of the two test techniques must consider the differences in the mode of testing. In the strip draw test, a new section of the coated workpiece is continuously drawn in between the dies as the test proceeds. If the lubricant is poorly adhered to the workpiece, the effect of the dies would be to scrape off the lubricant coating and thereby cause large increases in the friction as the test proceeds. If the lubricant is tightly adhered to the workpiece, then consistent friction results should be obtained as the test proceeds. It would also be possible that the initial portion of the drawing operations conditions the die to allow an effective reduction in the friction as the test proceeds.

For the ring test, the only newly coated workpiece material that can be brought in between the dies would result from the fold over of the axial surface of the ring. This new surface is more probably offset by exposure of new uncoated surface from the plastic deformation process. In addition to this difference, the high deformation pressures associated with the ring test can either cause squeezing out of more fluidish lubricants or cause dishing of the ring surface which effectively entraps the lubricant. When a comparison is made of lubricants evaluated in the "just applied" condition versus the cured condition, Table 4 and 5, it can be seen that both tests indicate the friction stresses of cured lubricants are about twice the value of the "just applied" condition. Some variation is evident, however.

The results from either test in the evaluation of dry graphite films do not show significant variations. For two of the non-graphite type lubricants, J-Wax and MS-122, results from the ring test showed definite lower values of friction. The exact explanation of this effect is not known, but is probably attributable to these lubricants being entrapped as the ring surfaces become dished.

SECTION VI

CONCLUSIONS

The results of this study allow the following conclusion to be made:

1. The anti-friction characteristics of lubricants for sheet forming operations are strongly dependent upon the amount of fluid carrier substance remaining in the lubricant at time of test.

2. Fluid containing lubricants show constant interface shear response in lightly loaded applications. The frictional shear resistance stresses are almost constant and the ratio of the frictional restraint to the normal applied pressure decreases with increasing normal pressure.

3. Lubricants without retained fluids show a constant coefficient of friction response in lightly loaded test conditions. The frictional restraint stress increases with increasing normal applied stress.

4. Lubricants evaluated in the cured or dried conditions gave a more consistent response in testing, but in general indicated higher frictional shear resistance.

5. Drawing speed variations evaluated at 15 ips and 1.5 ips did not indicate a significant effect on frictional response of the lubricant.

6. Die surface finish as measured by peak to valley roughness did not cause a significant effect on the frictional response of the lubricant between roughness values of 1.0 micro-inch and 32 micro-inches.

7. The results from the ring compression test indicated approximately the same trend in lubricant response as did the results from the variable-die-pressure strip draw test. The effect of the large pressure differences between these two tests could not be correlated with the resultant frictional shear of the film because of the lack of intermediate pressure data.

REFERENCES

1. Eary, D. F. and E. A. Read, Techniques of Pressworking Sheet Metal, 2nd Ed., Prentice Hall, Englewood Cliffs, N. J., 1974.

2. Keeler, S. P., "Understanding Sheet Metal Formability", A series of 6 articles, Sheet Met., Ind., 48, Nos. 5-10,(1971).

3. Hecker, S. S., "Formability of HSLA Steel Sheets", Metal Engineering Quarterly, 13, (3), August 1973, pp. 42-8.

4. Ghosh, A., "A Method for Determining the Coefficient of Friction in Punch Stretching of Sheet Metals", General Motors Research Laboratories Research Publication, GMR-2311, December 1976.

5. Goodwin, G. M., "Application of Strain Analysis to Sheet Metal Forming Problems in the Press Shop", SAE Paper 680093, pp. 1-12 (Reference cited by Keeler in Reference 2).

6. Keeler, S. P., (Part V of Reference 2, "Die Design and Lubrication").

7. Male, A. T. and V. DePierre, "The Validity of Mathematical Solutions for Determining Friction from the Ring Compression Test", TRANS ASME, Journal of Lubrication Technology, 1970, pp. 389-397.

8. Saul, G., A. T. Male, and V. DePierre, "A New Method for the Determination of Material Flow Stress Values Under Metalworking Conditions", Metal Forming: Interrelation Between Theory and Practice, Ed., A. L. Hoffmanner, 1971, Plenum Press.

9. DePierre, V. and F. Gurney, "A Method for Determination of Constant and Varying Friction Factors During Ring Compression Testing", Journal of Lubrication Technology, TRANS ASME, 1974, 96, Series F, (3), p. 482.

10. Pope, M. H., L. Robins, and J. T. Barry, "Lubrication Aspects of the Deep Drawing of Stainless Steel, Titanium and Nickel-Base Alloys at Elevated Temperatures", ASLE Paper No. 69LC-1.

11. Schey, J. A., "The Validity of Various Friction Concepts in Deformation Processing", Proceedings NAMRC-IV Fourth North American Metalworking Research Conference, May 1976, p. 108.

12. Male, A. T., and V. DePierre, "The Relative Validity of the Concepts of Coefficient of Friction and Interface Friction Shear Factor for Use in Metal Deformation Studies", ASLE Transactions, 16, (3), p. 177.

13. Vdovin, V. F., "Technological Properties of Glass-Base Lubricants Used in Extrusion", pp. 220-222 from Dnepropetrovsk, Scientific Transactions No. 53, 1967, English Translation by Foreign Technology Division, USAF, FTD-MT-24-318-69, 31 December 1969.

TABLE 1

Chemical Composition of Test Material

Material	Composition							
	Zn	Mg	Mn	Cu	Cr	Si	Fe	Al
7075 Al	5.8	2.9	.03	.1.7	.34	.02	.02	Bal.
	Al	V	Fe	C	O	Ti		
Ti-6Al-4V	6.6	4.2	.16	.015	.15	Bal.		

TABLE 2

Lubricants used in the Evaluation*

C-300	A spray mixture of graphite and M_oS_2 with a carrier
DGF	A graphite spray with a carrier
MS-122	A fluorocarbon spray in a carrier
F-33	A silicon spray in a carrier
J-WAX	A commercial paste wax polish
IC-665	A commercial sheet forming lubricant
G-203A	A commercial sheet forming lubricant composed of graphite dispersed in water, oils or solvents
G-231	A commercial sheet forming lubricant composed of graphite dispersed in water oils or solvents
HYDRO	A commercial sheet forming lubricant composed of graphite dispersed in water oils or solvents

*The lubricants listed on this table were applied and tested in a manner to obtain significant test variations. No attempt was made to utilize these lubricants in the manner recommended by the manufacturer. Results from the evaluation are not meant to refute nor to endorse the characteristics of the particular lubricant.

TABLE 3

Friction Ratios of Sheet Forming Lubricants in Elastic Drawing at Low to Moderate Hold Down Pressures

Material	Lube	Condition Lube †	Condition Die *	Draw Speed (ipm)	Initial/Maximum Friction Ratio At Indicated Hold Down Pressure 305 psi	610 psi	915 psi
7075 Al	C-300	J.A.	A.G.	15	.086/.182	.070/.075	.059/.066
		DRY	A.G.	15	.191/.200	.229/.231	.254/.264
		DRY	L.P.	15	.165/.175	.248/.261	.269/.281
		DRY	A.G.	1.5	.214/.214	.268/.244	.269/.276
7075	DGF	J.A.	A.G.	15	.140/.186	.077/.093	.038/.062
		DRY	A.G	15	.204/.259	.175/.235	.176/.223
		DRY	L.P.	15	.267/.309	.350/.380	.263/.289
		DRY	A.G.	1.5	.172/.214	.198/.257	.199/.315
7075	J-WAX	J.A.	A.G.	15	.089/.125	.079/.135	.053/.160
		DRY	A.G.	15	N.D.	N.D.	N.D.
		DRY	L.P.	15	.140/.151	.159/.163	.180/.186
		DRY	A.G.	1.5	.092/.092	.150/.151	.159/.159
7075	HYDRO	J.A.	A.G.	15	.229/lost	.194/lost	.276/lost
		DRY	A.G.	15	.138/.136	.128/.143	.125/.135
		DRY	L.P.	15	.118/.128	.132/.151	.135/.158
7075	G-231	J.A.	A.G.	15	.289/.289	.168/.168	.161/.161
		DRY	A.G.	15	.153/.162	.165/.175	.181/.207
		DRY	L.P.	15	.149/.149	.172/.182	.195/.196
7075	G-203A	J.A.	A.G.	15	.051/.099	.051/.095	.041/.053
		DRY	A.G.	15	.149/.153	.168/.185	.163/.173
		DRY	L.P.	15	lost	lost	lost
7075	IC-665	J.A.	A.G.	15	.049/.058	.045/.067	.038/.049
		DRY	A.G.	15	.157/.159	.168/.177	.171/.191
		DRY	L.P.	15	lost	lost	lost
Ti-6-4	HYDRO	DRY	A.G.	15	.147/.176	.134/.139	.115/.126
		J.A.	A.G.	15	.121/.1[illegible]3	.258/.271	.233/.254
Ti-6Al	G-231	DRY	A.G.	15	.147/.176	.163/.205	.106/.113
		J.A.	A.G.	15	.153/.191	.242/.291	.237/.257
Ti-6Al	IC-665	DRY	A.G.	15	N.D.	.156/.165	.174/.176
		J.A.	A.G.	15	.051/.091	.051/.070	.129/.161
Ti-6Al	G-203A	DRY	A.G.	15	N.D.	.163/.174	.149/.164
		J.A.	A.G.	15	.051/.058	.032/.041	.051/.077
Ti-6Al	DGF	J.A.	A.G.	15	.172/.181	.210/.217	.221/.226
Ti-6Al	J-WAX	J.A.	A.G.	15	.191/.212	.267/.274	.289/.301

L. P. - Lapped smoother than 1 micro-inch finish; *A. G. - As ground approximately 32 micro-inch finish; †J. A. - Just-applied within 30 secs. of testing; †DRY - Applied at least 24 hours prior to testing; N. D. - Not Determined; Lost - Data lost because of test situations.

TABLE 4

Friction Ratios of Sheet Forming Lubricants in
Elastic Drawing at High Hold-Down Pressures

Material	Lube	Condition		Draw Speed	Initial/Maximum Friction Ratio At Indicated Hold-Down Pressure			
		Lube	Die	(ipm)	1220 psi	1525 psi	1830 psi	2135 psi
7075	J-WAX	DRY	A.G.	15	.133/.137	.135/.142	.130/.135	.109/.111
7075	HYDRO	DRY	A.G.	15	.115/.119	.112/.125	.115/.127	.118/.132
7075	IC-665	J.A.	A.G.	15	.051/.069	.032/.178	.053/.245	.049/.240

TABLE 5

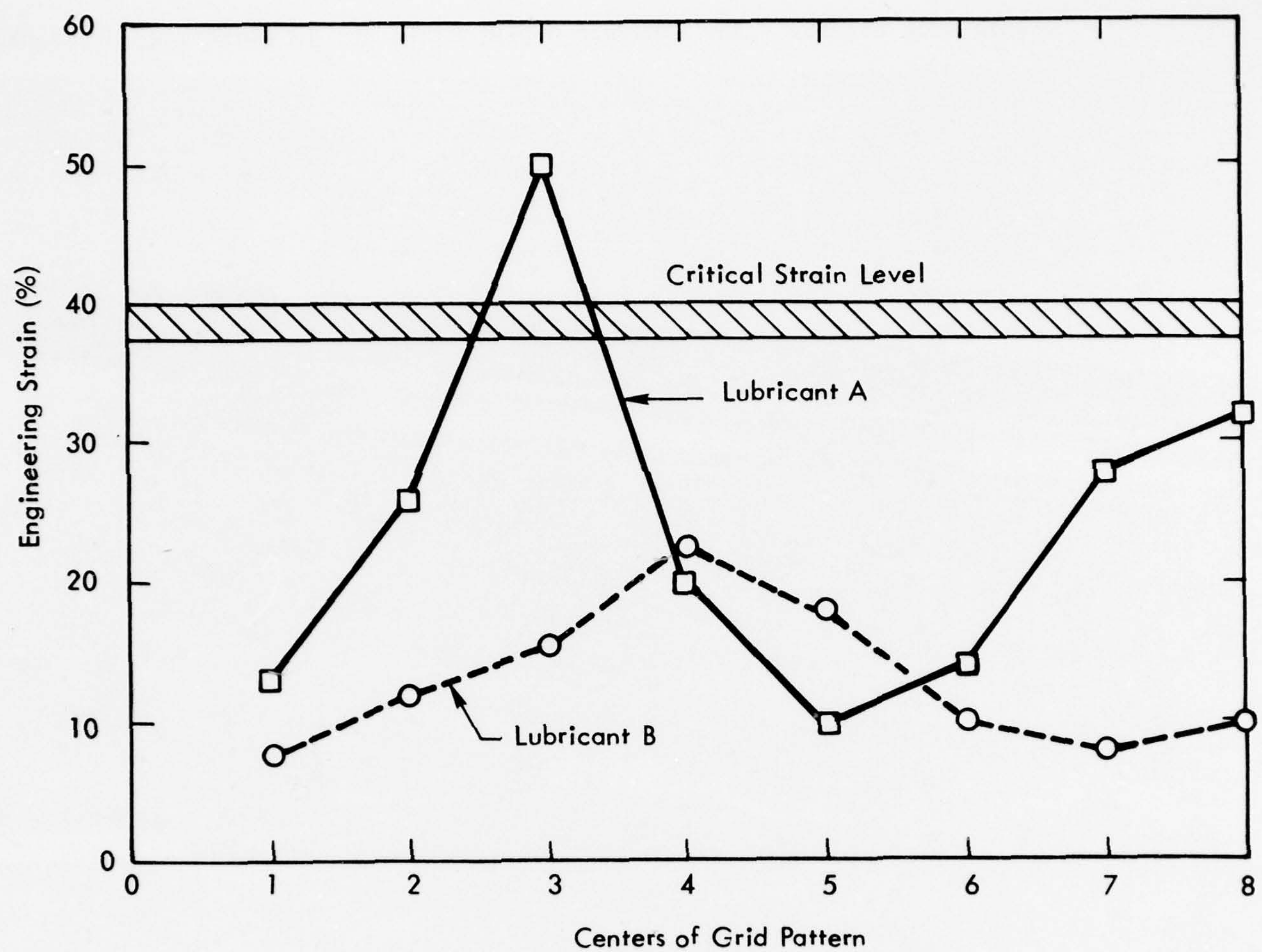
Interface Friction of Lubricants During Ring Forging of Sheet

Forge Number	Lube Type	ΔID (%)	ΔH (%)	Condition	m	c (ksi)
4691	C-300	14.5	11	Cured	.19	3.06
4693	C-300	22.2	15	Cured	.22	3.50
4692	C-300	34.9	26	Cured	.10	2.72
4694	DGF	19.6	16	Cured	.12	2.47
4695	DGF	26.8	18	Cured	.18	4.22
4696	DGF	38.3	23	Cured	.19	3.82
4698	J-WAX	9.6	11	Cured	.07	1.34
4697	J-WAX	13.4	18	Cured	.05	1.09
4699	J-WAX	23.1	28	Cured	.05	1.28
5033	J-WAX	2.1	14	J-APP	.02	.48
5034	J-WAX	13.8	31	J-APP	.03	.89
5035	J-WAX	21.0	33	J-APP	.03	1.02
5036	J-WAX	7.1	12	Cured	.05	1.02
5037	J-WAX	21.4	26	Cured	.05	1.31
5038	J-WAX	30.7	36	Cured	.04	1.63
4701	MS-122	1.4	10	Cured	.19	3.08
4700	MS-122	5.2	17	Cured	.14	2.17
4702	MS-122	10.3	22	Cured	.14	3.26
4703	IC-665	4.3	4	Cured	.14	2.17
4704	IC-665	16.2	12	Cured	.19	3.08
4705	IC-665	42.2	26	Cured	.14	3.26
5025	IC-665	23.0	18	Cured	.12	2.85
5021	IC-665	1.6	5	J-APP	.03	.48
5022	IC-665	4.1	15	J-APP	.03	.65
5023	IC-665	14.2	25	J-APP	.04	1.26

TABLE 5 (CON'T)

Interface Friction of Lubricants During Ring Forging of Sheet

Forge Number	Lube Type	ΔID (%)	ΔH (%)	Condition	m	c (ksi)
4706	HYDRO	10.4	8	Cured	.21	2.99
4707	HYDRO	20.5	16	Cured	.14	2.57
4708	HYDRO	36.0	23	Cured	.16	3.36
5027	HYDRO	1.5	3	J-APP	.04	.62
5028	HYDRO	5.1	13	J-APP	.03	.67
5029	HYDRO	22.9	32	J-APP	.05	1.62
5030	HYDRO	7.8	9	Cured	.08	1.76
5031	HYDRO	23.2	20	Cured	.10	2.54
5032	HYDRO	38.9	26	Cured	.12	3.77
5008	G-231	0.0	5	J-APP	.02	.35
5009	G-231	1.9	25	J-APP	.01	.22
5010	G-231	4.8	38	J-APP	.02	.56
5011	G-231	2.4	4	Cured	.05	.92
5012	G-231	9.1	7	Cured	.22	3.40
5013	G-231	29.1	23	Cured	.10	2.69
4713	G-203A	28.9	19	Cured	.18	3.56
4714	G-203A	53.2	27	Cured	.23	4.37
5014	G-203A	-1.5	14	J-APP	.02	.36
5016	G-203A	0.0	19	J-APP	.02	.48
5015	G-203A	2.4	20	J-APP	.02	.49
5017	G-203A	12.0	34	J-APP	.02	.47
5019	G-203A	30.8	24	Cured	.10	2.56
5020	G-203A	53.3	36	Cured	.08	3.18
4715	F-33	9.3	10	Cured	.09	1.81
4716	F-33	15.3	13	Cured	.12	3.42
4717	F-33	19.9	20	Cured	.07	3.16



(after Goodwin referenced by Keeler)

Figure 1. Reduction in Peak Strain at a Critical Region in Stamping of an Automobile Hood. The reduction was achieved by changing one "good" lubricant for another.

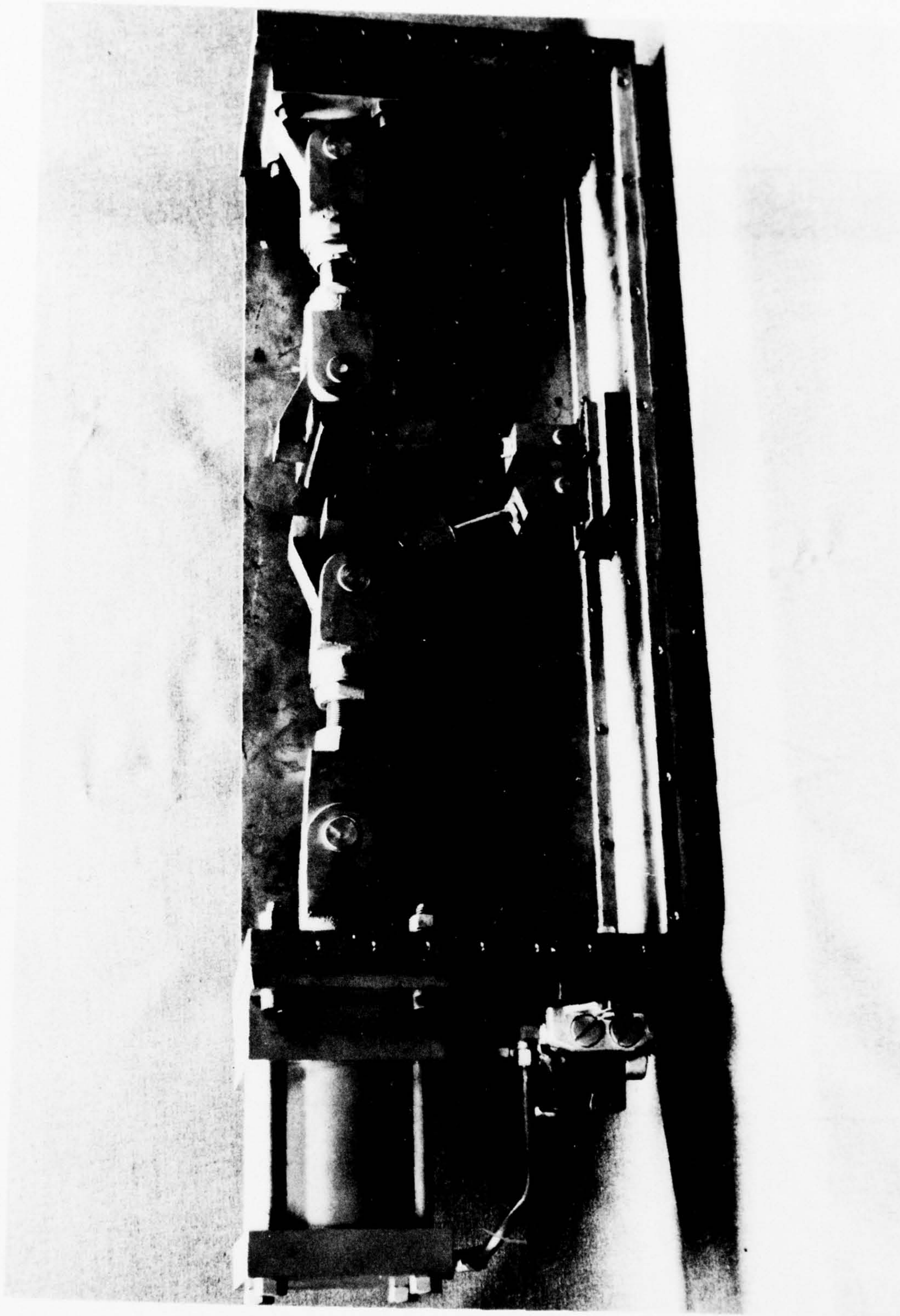


Figure 2. Photograph of the variable-die pressure strip drawing apparatus.

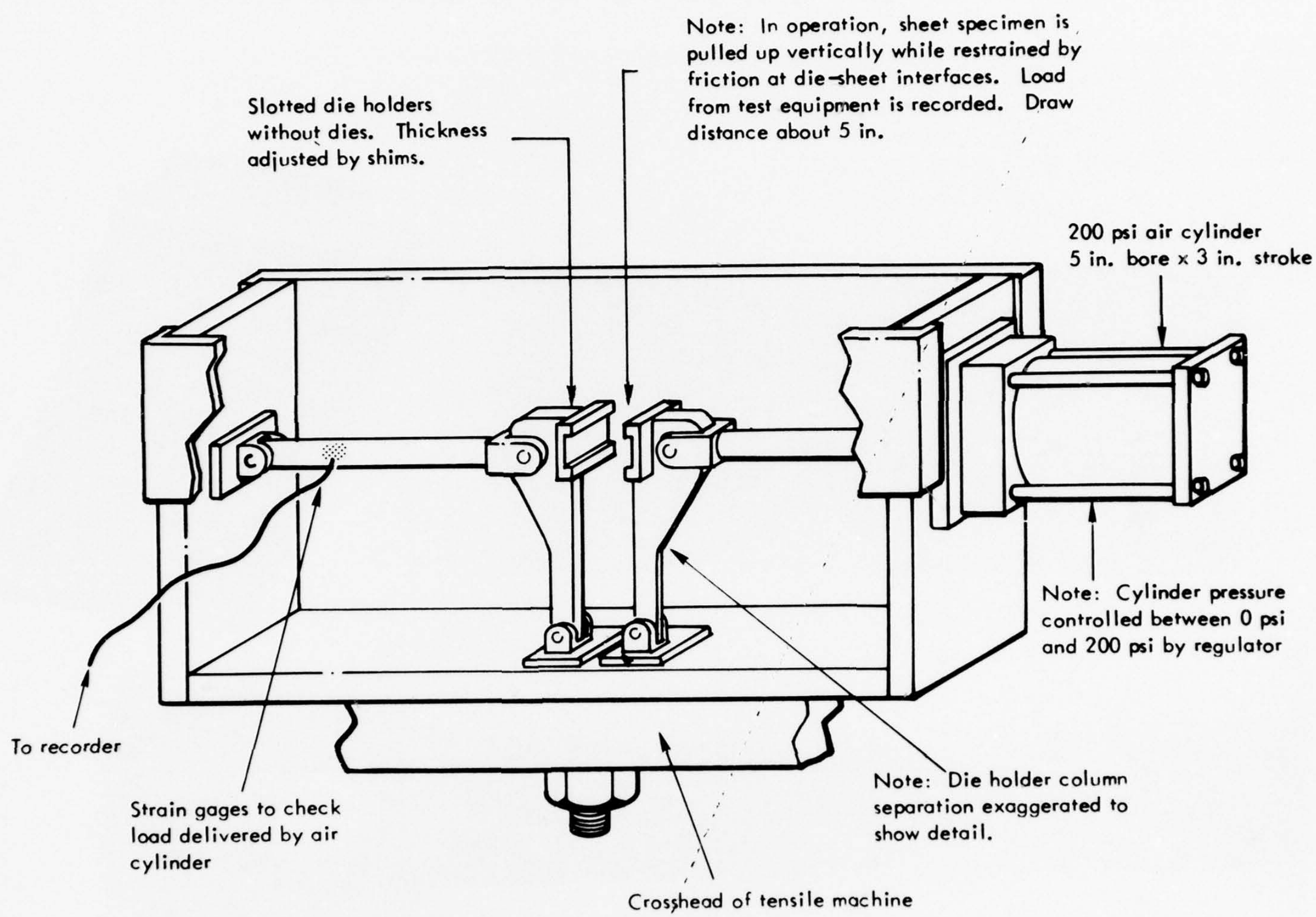


Figure 3. Schematic Drawing of the Variable-Die-Pressure Strip Draw Apparatus

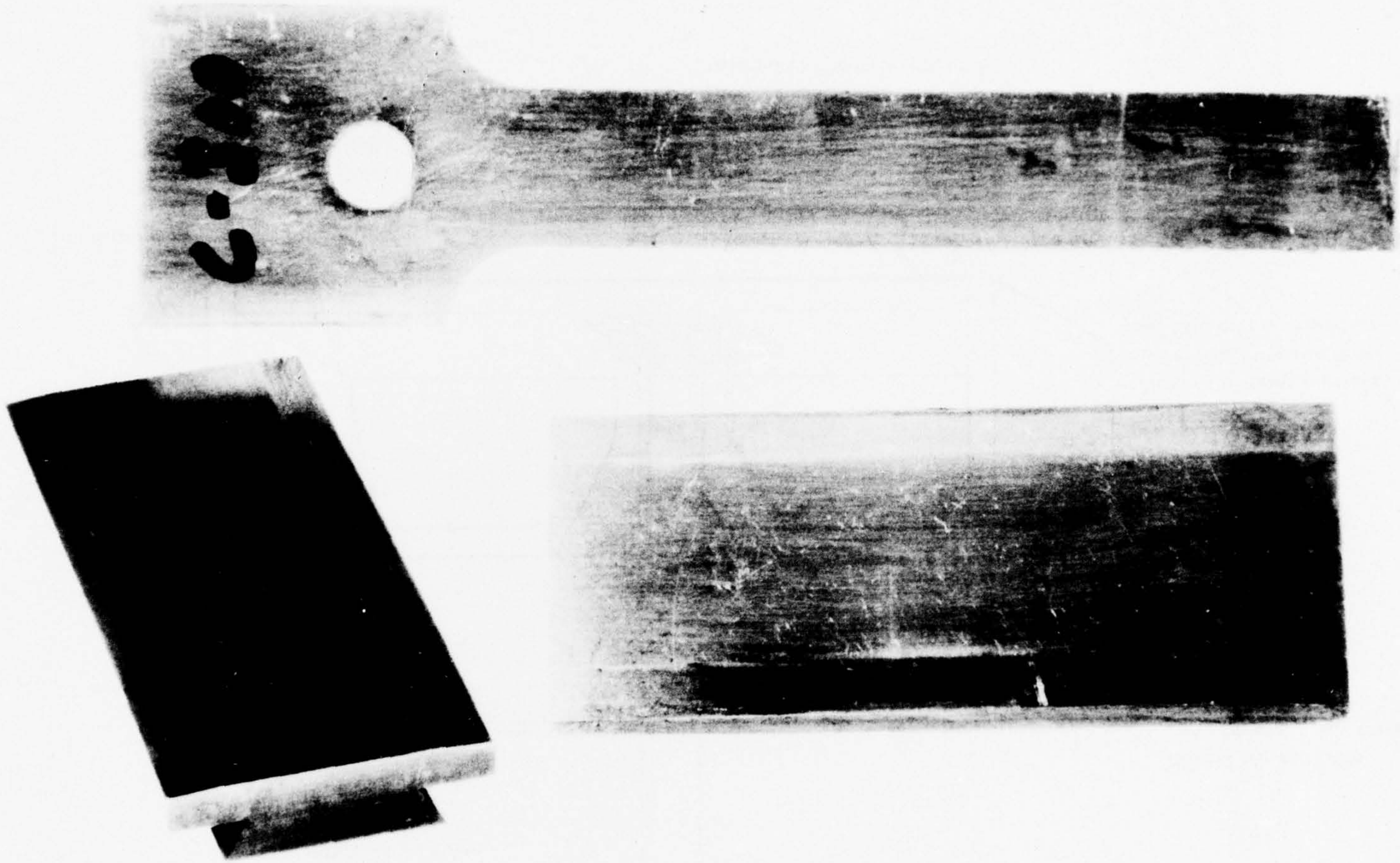


Figure 4. Photograph of the strip-draw specimen and the dovetail locked interchangeable dies used in the evaluation.

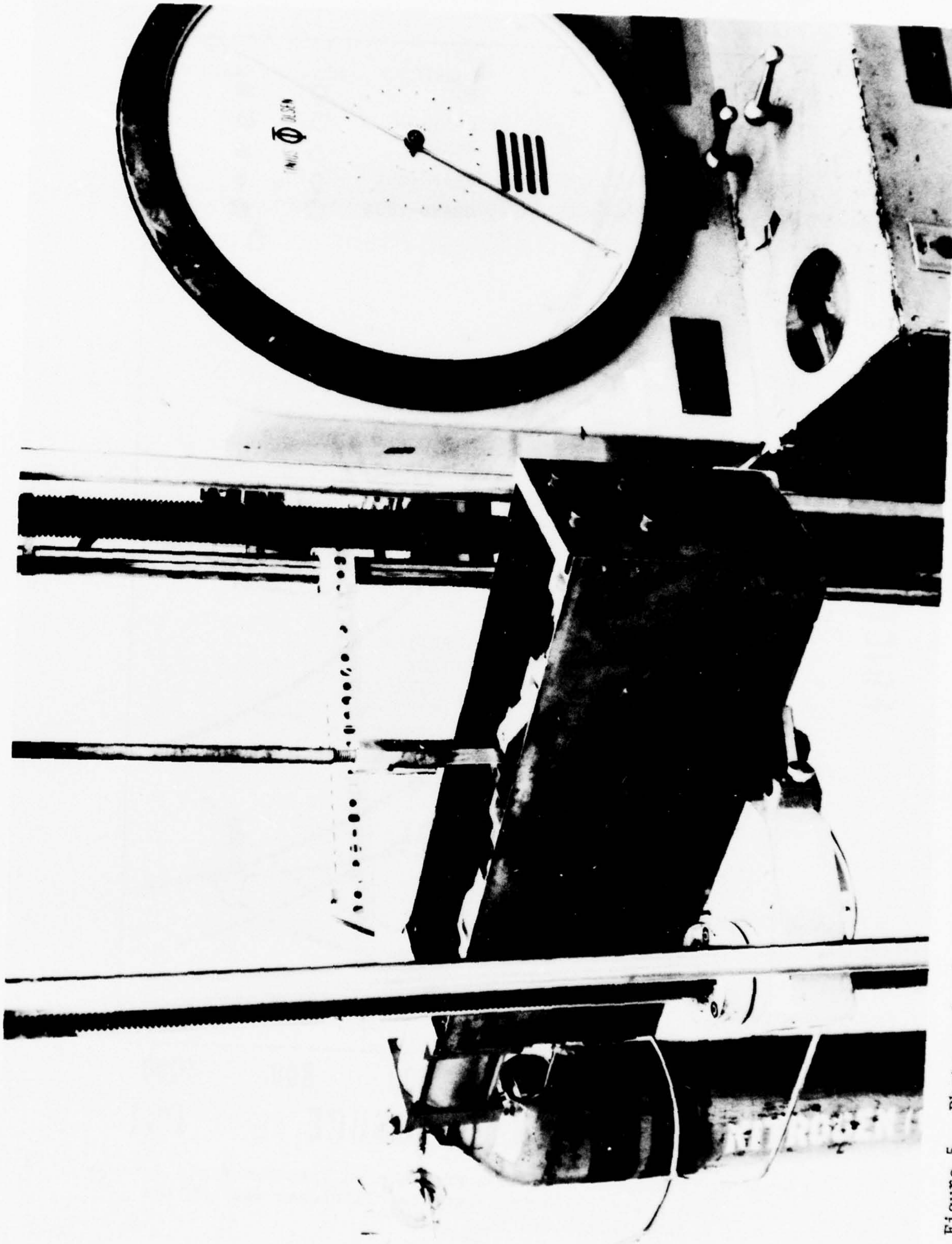


Figure 5. Photograph of test set-up for lubricant evaluation in strip-drawing.

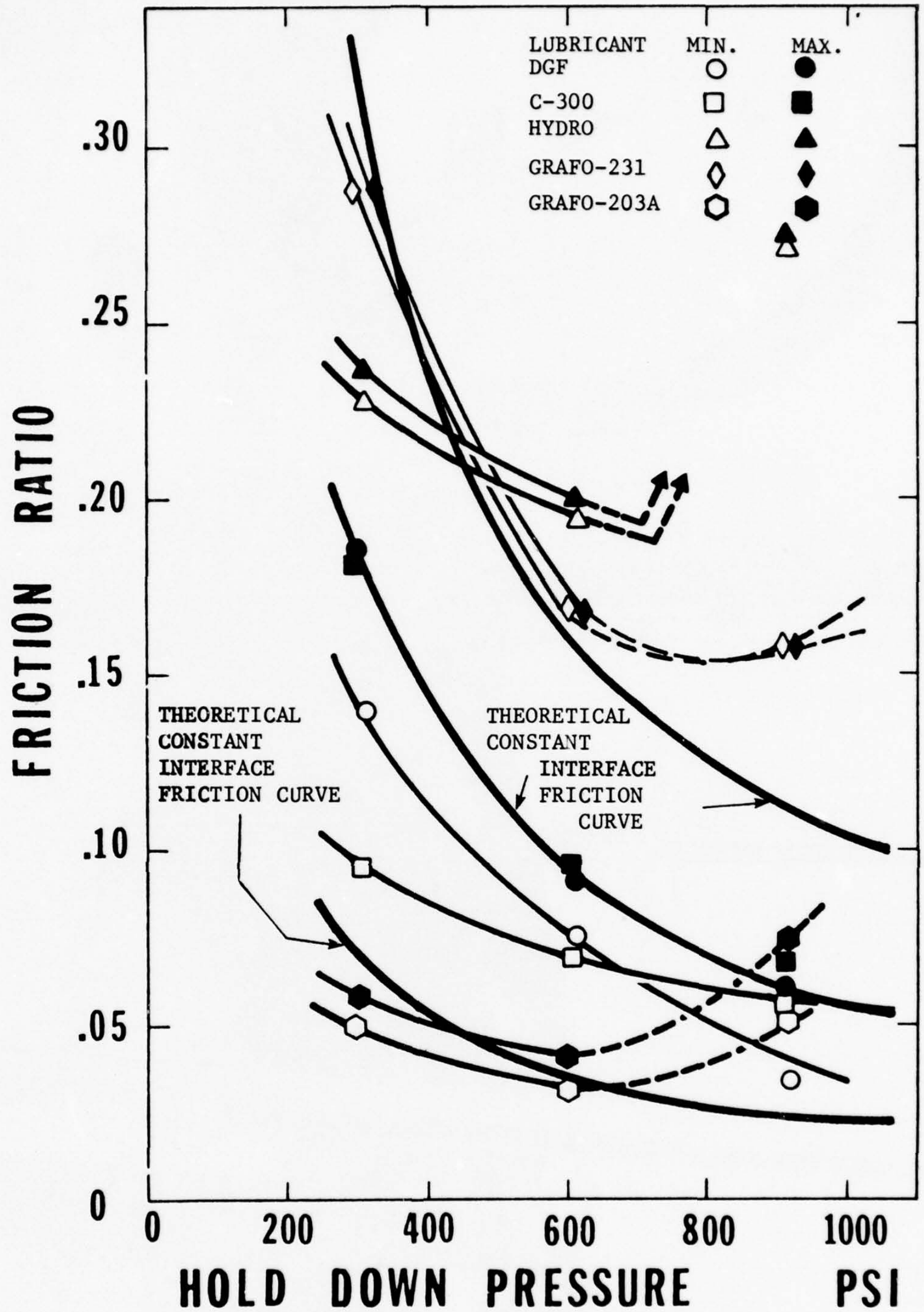


Figure 6. Effect of hold-down pressure on friction ratio during strip-drawing where the lubricant was applied just before testing.

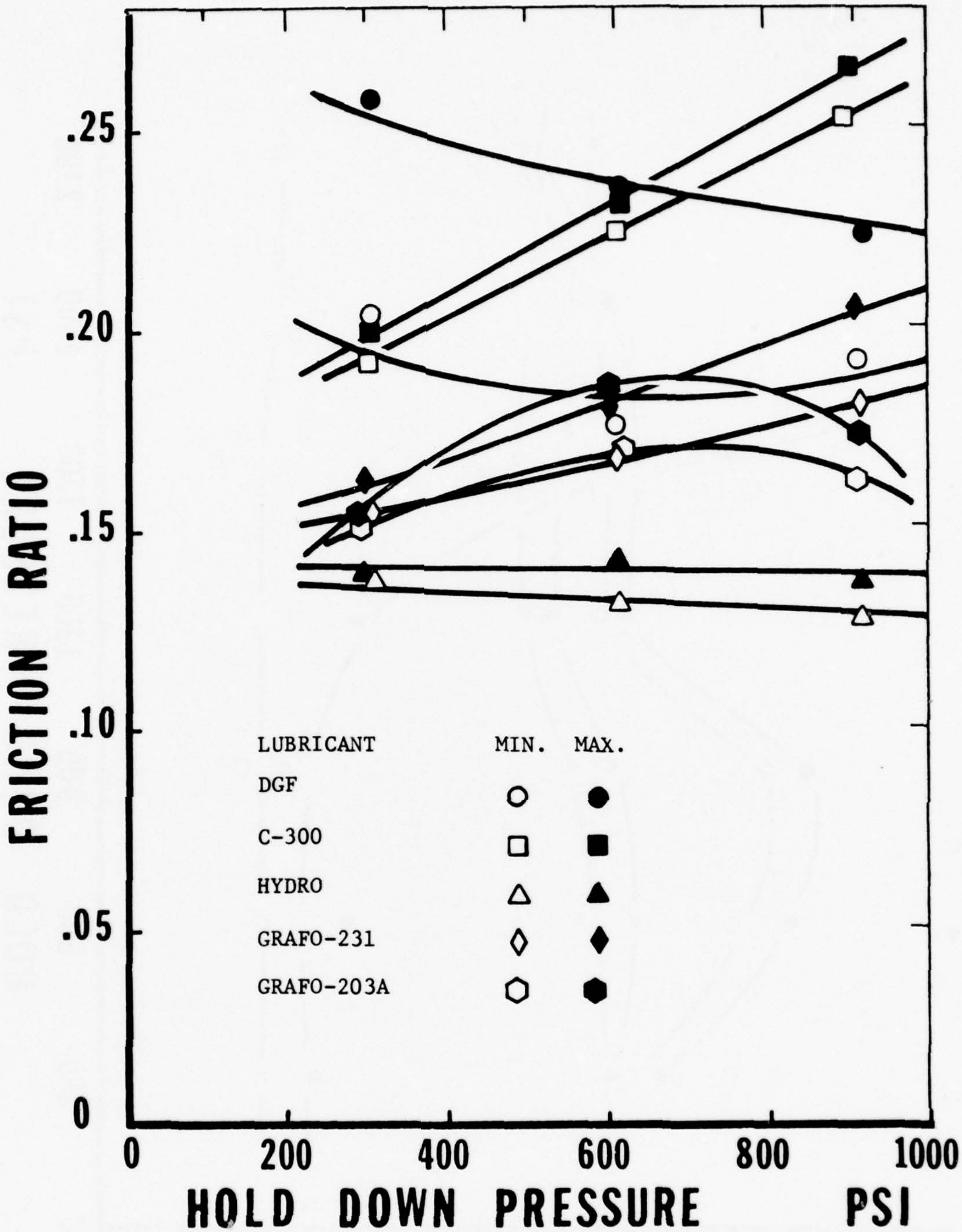


Figure 7. Effect of hold-down pressure on friction ratio during strip-drawing where lubricant was cured before testing.

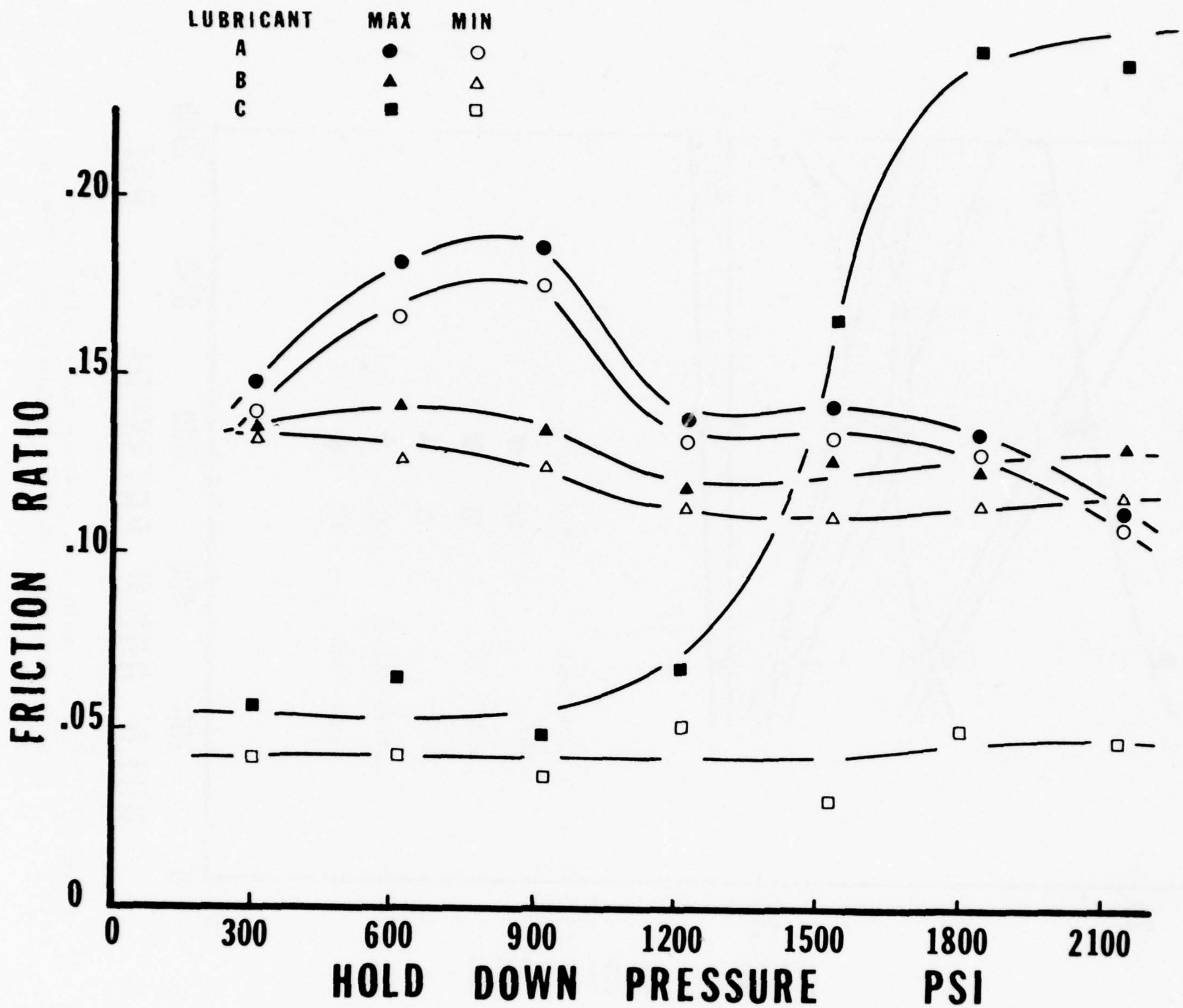


Figure 8. Effect of very high hold-down pressures on friction ratio of selected lubricants at selected conditions.

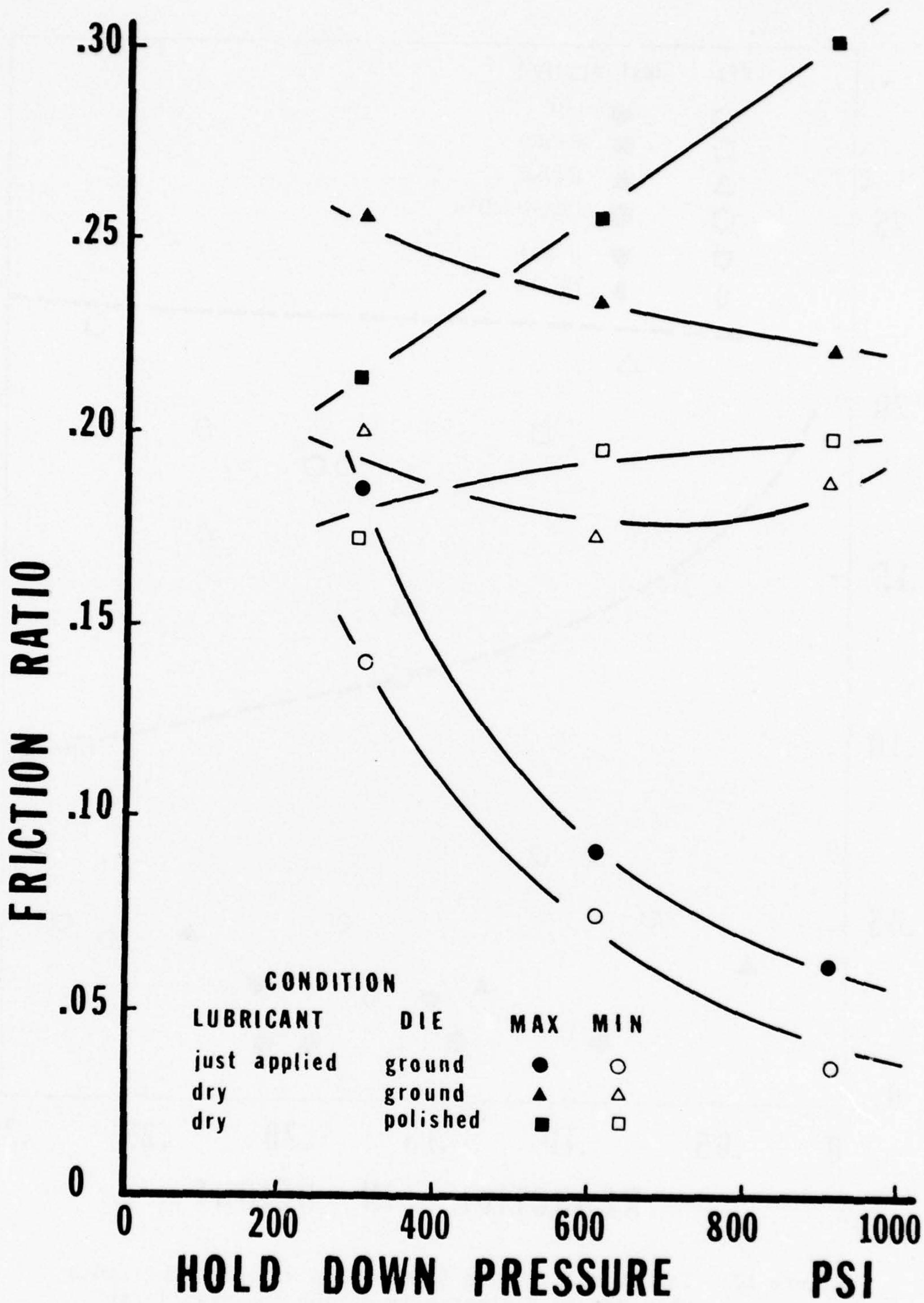


Figure 9. Effect of variation in die surface condition, lubricant curing time and draw speed on the resulting friction ratio of dry film graphite.

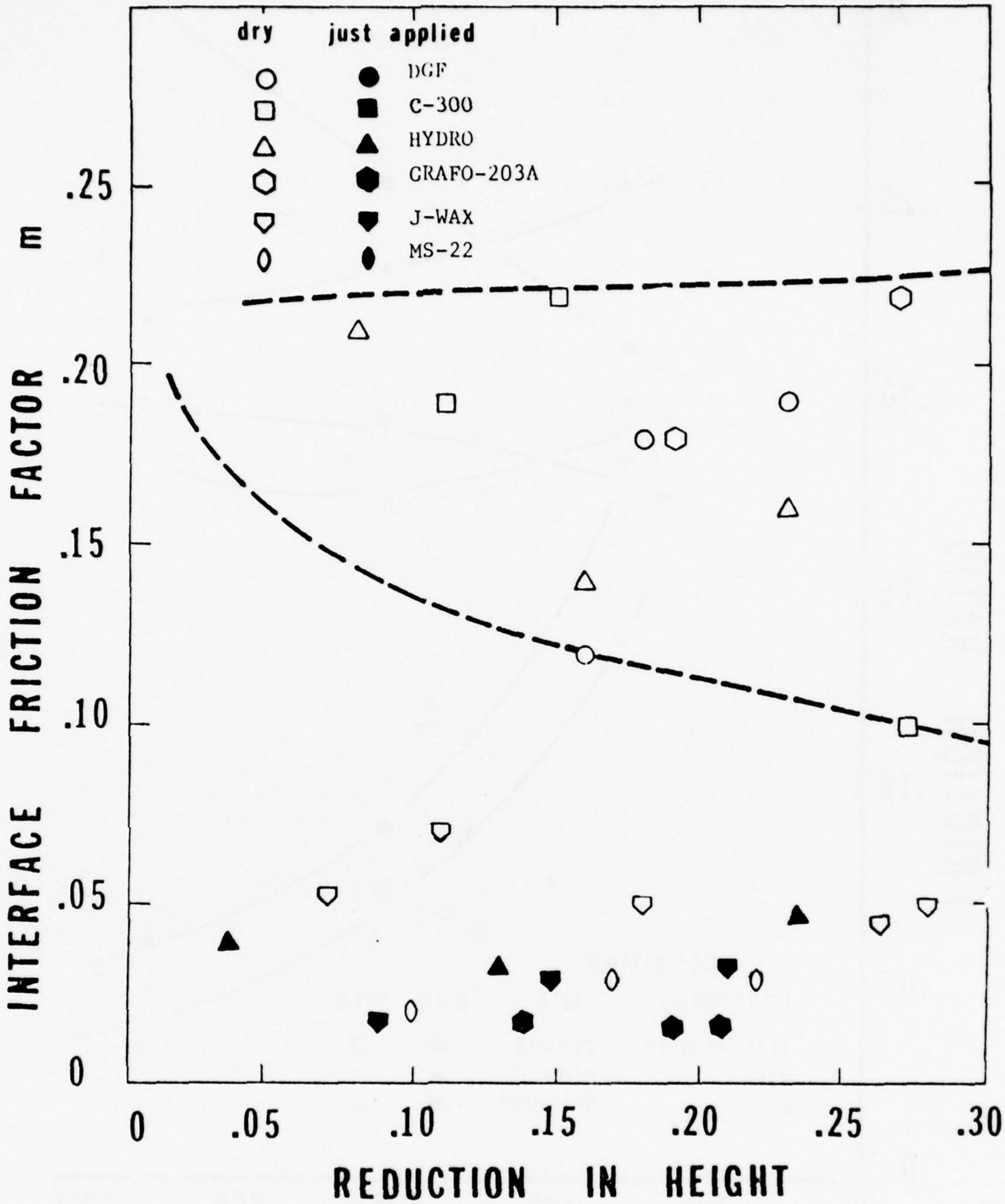


Figure 10. Interface friction factor from various lubricants when deformed plasticity during the ring forge test.

APPENDIX
APPLIED METAL PROCESSING
TITANIUM BASE

Extrusion Number	Agency	Alloy	Temp. ^oF	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6754	AFML/LLS	Ti-8V-4Cr-2Mo-2Fe-3Al	1500	5.3:1	8871	60^o	97	1.8	Good
6755	AFML/LLS	Ti-8V-4Cr-2Fe-3Al	1500	5.3:1	8871	60^o	108	1.8	Good
6756	AFML/LLS	Ti-15V-3Cr-3Al-3Sn	1500	5.3:1	8871	60^o	111	1.8	Good
6757	AFML/LLS	Ti-15V-3Cr-3Al-3Sn	1500	5.3:1	8871	60^o	109	1.8	Good
6764	Pratt & Whitney	Ti-32.5Al-4.6Nb-.5W	2550	6:1	7740	60^o	120	1.4	Good
6765	Pratt & Whitney	Ti-32.5Al-4.6Nb-.5W	2550	6:1	7740	60^o	140	1.4	Good
6766	Pratt & Whitney	Ti-32.5Al-4.6Nb-.5W	2550	6:1	7740	60^o	120	1.4	Good
6767	Pratt & Whitney	Ti-32.5Al-4.6Nb-.5W	2550	6:1	7740	60^o	120	1.4	Good
6768	AFML/LLS	Ti-5Al-5Sn -2Zr-2Mo-.25Si	1600	6:1	0010	60^o	157	2.1	Good
6769	AFML/LLS	Ti-5Al-5Sn 2Zr-2Mo-.25Si	1900	6:1	0010	60^o	59	2.6	Excellent
6770	AFML/LLS	Ti-5Al-5Sn -2Zr-2Mo-.25Si	1900	6:1	0010	60^o	68	2.6	Excellent
6788	AFML/LLM-1	Ti-36.3Al Powder	2575	10:1	7740	90^oR	51	1.3	Good
6790	AFML/LLM-1	Ti-28.6Al Powder	2575	----	7740	90^oR	42	1.5	Good

TITANIUM BASE

Extrusion Number	Agency	Alloy	Temp. ^{o}F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6791	AFML/LLM-1	Ti-30.5Al	2575	----	7740	90^{o}R	40	1.5	Good
6792	AFML/LLM-1	Ti-32.5Al	2575	----	7740	90^{o}R	44	1.5	Good
6793	AFML/LLM-1	Ti-34.25Al	2575	----	7740	90^{o}R	43	1.4	Good
6821	Pratt & Whitney	Ti-32.5Al-4.6Nb-5W	2550	6:1	7740	60^{o}	38	1.5	Good
6822	Pratt & Whitney	Ti-32.5Al-4.6Nb-5W	2550	6:1	7740	60^{o}	39	1.5	Good
6823	Pratt & Whitney	Ti-32.5Al-4.6Nb-5W	2550	6:1	7740	60^{o}	38	1.4	Good
6833	AFML/LLM	Ti-10V-2Fe-3Al	1150	5.8:1	8871	90^{o}	185	.3	----
6837	AFML/LLM	Ti-10V-2Fe-3Al	1150	5.9:1	8871	60^{o}	178	0.5	Good
6859	AFML/LLM	Ti-10V-2Fe-3Al	1150	5.8:1	8871	60^{o}	173	1.2	Good
6860	AFML/LLM-1	Ti-32.5Al-4.6Nb-5W	2550	15.92:1	7740	60^{o}	55	1.5	Good
6861	AFML/LLM-1	Ti-28.6Al	2550	26:1	7740	60^{o}	62	1.5	----
6862	AFML/LLM-1	Ti-14.6Al-10Nb-4W	2200	26:1	0010	60^{o}	65	1.4	----
6872	AFML/LLS	Ti-31%Al	2550	20:1	7740	90^{o}R	43	1.5	Good
6874	AFML/LLM-1	Ti-51%Al	2575	26:1	7740	60^{o}	76	----	Good
6912	AFML/LLM-1	Ti-27%Al	2200	26:1	0010	60^{o}	54	1.6	Good
6913	AFML/LLM-1	Ti-27%Al	2200	26:1	0010	60^{o}	57	1.6	Good
6914	AFML/LLM-1	Ti-24%Al-11%Nb	2200	26:1	0010	60^{o}	54	1.6	Good

APPLIED METAL PROCESSING

TITANIUM BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6915	AFML/LLM-1	Ti-24%Al-11%Nb	2200	26:1	0010	60°	54	1.6	Good
6923	AFML/LLM-1	Ti-25%Al-8%Nb	2575	26:1	7740	60°	81	1.6	Good
6924	AFML/LLM-1	Ti-25%Al-8%Nb-5%W	2575	26:1	7740	60°	70	1.6	Good
6926	AFML/LLM-1	Ti-26.5W/o-Al	2575	26:1	7810	60°	70	1.6	Good
6927	AFML/LLM-1	Ti-34.3W/o-Al	2575	26:1	7810	60°	97	1.5	Good
6928	AFML/LLM-1	Ti-34W/o-Al-4.5W/o-W	2575	26:1	7810	60°	127	1.5	Good
6929	AFML/LLM-1	Ti-36W/o-Al	2575	26:1	7810	60°	89	1.6	Good
6930	AFML/LLM-1	Ti-32W/o-Al-9W/o-W	2575	26:1	7810	60°	81	1.6	Good
6931	AFML/LLM-1	Ti-.331W/o-Al-14W/o-C	2575	6:1	7810	60°	----	----	----
6932	GE	Ti-6Al-4V	1800	44:1	0010	120°	105	2.8	Good
6933	GE	Ti-6Al-4V	1800	44:1	0010	120°	108	2.7	Good
6934	GE	Ti-6Al-4V	1800	44:1	0010	120°	105	2.8	Good
6935	GE	Ti-6Al-4V	1800	44:1	0010	120°	105	2.7	Good
6936	GE	Ti-6Al-4V	1800	44:1	0010	120°	----	----	----
6937	GE	Ti-6Al-4V	1800	44:1	0010	120°	----	----	Good
7052	AFML/LLM	2Ti-10V-2Fe-3Al	1150	10:1	8871	60°	192	1.1	Good

APPLIED METAL PROCESSING

TITANIUM BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
7053	AFML/LLM	Ti-10V-2Fe-3Al	1150	10:1	8871	60°	193	1.1	Good
7068	AFML/LLS	Ti-5Al-5Sn-2Zr-2Mo-0.25Si	1600	6:1	0010	60°	135	2.7	Good
7069	AFML/LLS	Ti-5Al-5Sn 2Zr-2Mo-0.25Si	1900	6:1	0010	60°	43	3.1	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6761	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16:1	Poly	90°	140	1.8	Good
6762	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16:1	Poly	90°	134	2.0	Good
6763	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16:1	Poly	90°	138	2.0	Good
6772	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16.3:1	Poly	90°	130	2.0	Good
6773	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16.3:1	Poly	90°	130	2.0	Good
6774	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	140	1.6	Good
6775	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	140	1.7	Good
6776	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	153	6.0	Good
6777	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	154	5.2	Good
6778	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16:1	Poly	90°	130	2.0	Good
6779	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16:1	Poly	90°	134	2.1	Good
6780	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20:1	Poly	90°	159	5.5	Good
6781	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20:1	Poly	90°	161	6.0	Good
6782	Pratt & Whitney	IN-100	1950	8:1	0010	60°	135	1.2	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{e_x} (ips)	Surface
6783	Pratt & Whitney	IN-100	2000	8:1	0010	60°	147	1.2	Good
6784	Pratt & Whitney	IN-100	1950	2:1	0010	60°	70	1.5	Good
6785	Pratt & Whitney	IN-100	1900	2:1	0010	60°	81	1.1	Good
6786	Pratt & Whitney	IN-100	1850	2:1	0010	60°	100	1.1	Good
6787	Pratt & Whitney	IN-100	1800	2:1	0010	60°	124	.9	Good
6794	Battelle	718	1900	Blank	Poly	90°	200	1.0	Good
6795	Battelle	718	1900	Blank	Poly	90°	200	1.0	Good
6796	Battelle	718	1900	Blank	Poly	90°	200	1.0	Good
6797	Battelle	718	1900	Blank	Poly	90°	194	1.0	Good
6798	Battelle	718	1900	Blank	Poly	90°	197	1.0	Good
6799	Battelle	718	1900	Blank	Poly	90°	192	1.0	Good
6800	Battelle	718	1900	Blank	Poly	90°	194	1.0	Good
6801	Battelle	718	1900	Blank	Poly	90°	200	1.0	Good
6802	Battelle	718	1900	Blank	Poly	90°	194	1.0	Good
6803	Battelle	718	1900	Blank	Poly	90°	197	1.0	Good
6804	Battelle	718	1900	Blank	Poly	90°	194	1.0	Good
6805	Battelle	718	1900	Blank	Poly	90°	194	1.0	Good
6806	Battelle	718	1900	10:1	0010	90°	184	.5	Good
6807	Battelle	718	2000	10:1	0010	90°	178	.5	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6808	Battelle	718	2000	10:1	0010	90°	178	1.4	Good
6809	Battelle	718	2000	10:1	0010	90°	167	2.0	Good
6810	Battelle	718	2000	10:1	0010	90°	173	2.0	Good
6811	Battelle	718	2000	10:1	0010	90°	170	2.1	Good
6812	Battelle	718	2000	10:1	0010	90°	167	2.1	Good
6813	Battelle	718	2000	10:1	0010	90°	173	1.9	Good
6814	Battelle	718	2000	10:1	0010	90°	173	2.0	Good
6815	Battelle	718	2000	10:1	0010	90°	170	2.0	Good
6816	Battelle	718	2000	10:1	0010	90°	173	2.0	Good
6817	Battelle	718	2000	10:1	0010	90°	170	1.9	Good
6819	Polymet	---	2000	9:1	Poly	60°	178	.7	Bad
6824	Sherritt Gordon	Ni-Base	1800	9.6:1	Poly	90°R	116	1.2	Good
6825	Sherritt-Gordon	Ni-Base	1800	10:1	Poly	90°R	113	1.1	Good
6826	Sherritt-Gordon	Ni-Base	1800	10:1	Poly	90°R	116	1.1	Good
6827	Sherritt-Gordon	Ni-Base	1900	10:1	Poly	90°R	113	1.1	Good
6828	Sherritt-Gordon	Ni-Base	1900	10:1	Poly	90°R	119	1.0	Good
6829	Sherritt-Gordon	Ni-Base	1900	10:1	Poly	90°R	111	1.0	Good
6830	Sherritt-Gordon	Ni-Base	2000	10:1	Poly	90°R	97	1.2	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6831	Sherritt-Gordon	Ni-Base	2000	10:1	Poly	90° R	103	1.2	Good
6832	Sherritt-Gordon	Ni-Base	2000	10:1	Poly	90° R	104	1.1	Good
6840	Pratt & Whitney	IN-100	1750	2:1	0010	60°	126	1.5	----
6841	Pratt & Whitney	IN-100	1700	2:1	0010	60°	135	.8	----
6847	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16.3:1	Poly	90°	132	2.2	Good
6848	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16.3:1	Poly	90°	138	1.9	Good
6849	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16.3:1	Poly	90°	138	1.9	Good
6850	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	154	4.5	Good
6851	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	156	4.5	Good
6852	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	20.5:1	Poly	90°	156	4.5	Good
6853	Pratt & Whitney	IN-100 Mod.	2050	8:1	0010	60°	117	1.1	Good
6854	Pratt & Whitney	MARM-200	2050	8:1	0010	60°	123	1.0	Good
6855	Pratt & Whitney	MARM-200	2150	20:1	0010	60°	119	1.2	Good
6856	Pratt & Whitney	Ni-Mo-Al	2150	20:1	0010	60°	135	1.0	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6857	Pratt & Whitney	B-1950	2100	8:1	0010	60°	105	1.2	Good
6858	Pratt & Whitney	Monoloy	2100	8:1	0010	60°	122	1.1	Good
6864	Polymet	Ni-Base	1700	12.5:1	Poly	90°	122	2.0	Good
6866	Pratt & Whitney	MARM-200 Mod.	2150	43:1	7052	120°	152	.9	Good
6867	Pratt & Whitney	MARM-200	2150	43:1	7052	120°	159	.7	Good
6868	Pratt & Whitney	Ni-Mo-Al	2200	43:1	7052	120°	167	.8	Good
6875	Pratt & Whitney	IN-100	1600	2:1	0010	60°	154	0.7	Fair
6876	Pratt & Whitney	IN-100	1650	2:1	0010	60°	154	0.7	Fair
6778	Stellite	Ni-16Cr-4Al-Y_2O_3	1900	16:1	Poly	90°	130	2.0	Good
6879	Pratt & Whitney	Ni-Mo-Al	2200	43:1	7052	120°	155	0.5	Good
6880	Pratt & Whitney	Ni-Mo-Al	2200	43:1	7052	120°	165	---	Good
6881	Pratt & Whitney	Ni-Mo-Al	2200	43:1	7052	120°	147	0.5	Good
6882	Pratt & Whitney	MARM-200 Mod.	2200	43:1	7052	120°	148	0.5	Good
6883	Pratt & Whitney	Ni-Cr-Al-N-γ	2200	43:1	7052	120°	139	0.5	Good
6884	Pratt & Whitney	Ni-Cr-Al-Ni-γ	2200	43:1	7052	120°	140	0.5	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6886	Pratt & Whitney	Ni-Cr-Al-γ+WC	2200	43:1	7052	120°	----	.7	Good
6887	Pratt & Whitney	Ni-Cr-Al-γ+WC	2200	43:1	7052	120°	157	1.0	Good
6888	Pratt & Whitney	Ni-Cr-Al-γ TiC+W	2200	43:1	7052	120°	159	1.0	Good
6889	Pratt & Whitney	Ni-Cr-Al-γ-Ti-B	2200	43:1	7052	120°	154	1.0	Good
6890	Pratt & Whitney	Ni-Cr-Al-γ+Ti-C^2	2200	43:1	7052	120°	147	1.1	Good
6891	Pratt & Whitney	Ni-Cr-Al-γ+Cb-C	2200	43:1	7052	120°	157	.9	Good
6892	Pratt & Whitney	Ni-Cr-Al-γ+Ti-C-Cb	2200	43:1	7052	120°	165	.9	Good
6893	Pratt & Whitney	Ni-Mo-Al	2200	43:1	7052	120°	178	.8	Good
6894	Pratt & Whitney	Ni-Mo-Al	2200	43:1	7052	120°	177	1.0	Good
6895	Pratt & Whitney	Hi-C Mod. AF2-1DA	2200	43:1	7052	120°	140	1.1	Good
6896	Pratt & Whitney	C. Mod. AF2-1DA	2200	43:1	7052	120°	132	1.3	Good
6897	Pratt & Whitney	C+B Mod. AF2-1DA	2200	43:1	7052	120°	135	1.2	Good
6898	Pratt & Whitney	B. Mod. MARM-200	2200	43:1	7052	120°	146	1.0	Good
6916	Pratt & Whitney	MARM-200	2200	44.6:1	0010	120°	146	1.0	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6917	Pratt & Whitney	MARM-200	2250	44.6:1	7052	120°	130	1.2	Excellent
6918	Pratt & Whitney	Monoloy-555	2250	44.6:1	7052	120°	154	1.0	Excellent
6919	Pratt & Whitney	MARM-200	2300	44.6:1	7052	120°	151	1.2	Good
6920	Pratt & Whitney	Ni-15Mo-8Al	2300	44.6:1	7052	120°	140	1.0	Good
6921	Pratt & Whitney	Ni-18Mo-8Al	2300	44.6:1	7052	120°	146	1.0	Good
6944	Pratt & Whitney	MARM-247	2250	44:1	0010	120°	146	1.1	Good
6945	Pratt & Whitney	MARM-247	2250	44:1	0010	120°	146	1.1	Good
6946	AiResearch Arizona	MARM-247	2200	43:1	0010	120°	155	1.0	Good
6947	AiResearch Arizona	MARM-247	2200	43:1	0010	120°	151	1.1	Good
6948	Pratt & Whitney	Ni-72.76Cr -2.4-(+)	1850	Blank	Poly	120°	192	1.0	Excellent
6949	Pratt & Whitney	Ni-72.76Cr -12.4-(+)	1850	Blank	Poly	120°	190	1.0	Excellent
6950	Pratt & Whitney	Ni-63.7-12.4Cr-(+)	1850	Blank	Poly	120°	193	1.0	Excellent
6951	Pratt & Whitney	Ni-63.76Cr -12.4-(+)	1850	Blank	Poly	120°	189	1.0	Excellent
6952	Pratt & Whitney	Ni-50.2Cr-12.4Co-22.5-(+)	1850	Blank	Poly	120°	192	1.0	Excellent

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	Ve_x (ips)	Surface
6953	Pratt & Whitney	Ni-50.26Cr -12.4Co- 9.0- (+)	1850	Blank	Poly	120°	192	1.0	Excellent
6954	Pratt & Whitney	Ni-55.00Cr -12.4Co-18-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6955	Pratt & Whitney	Ni-55.00Cr -12.4Co- 18-(+)	1850	Blank	Poly	120°	192	1.0	Excellent
6956	Pratt & Whitney	Ni-64.09- 12.4Cr- 22.5Co(+)	1850	Blank	Poly	120°	192	1.0	Excellent
6957	Pratt & Whitney	Ni-64.09Cr -12.4-9.0Co(+)	1850	Blank	Poly	120°	190	1.0	Excellent
6958	Pratt & Whitney	Ni-53.34- 12.4Cr-22.5Co(+)	1850	Blank	Poly	120°	192	1.0	Excellent
6959	Pratt & Whitney	Ni-53.34- 12.4Cr- 18.0Co(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6960	Pratt & Whitney	Ni-60.62- 12.4Cr- 9.0Co-(+)	1850	Blank	Poly	120°	196	1.0	Excellent
6961	Pratt & Whitney	Ni-60.09- 12.4Cr- 9.0Co-(+)	1850	Blank	Poly	120°	196	1.0	Excellent
6962	Pratt & Whitney	Ni-62.34- 12.4Cr- 9.0Co-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6963	Pratt & Whitney	Ni-62.34- 12.4Cr- 9.0Co-(+)	1850	Blank	Poly	120°	194	1.0	Excellent

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6964	Pratt & Whitney	Ni-57.99Cr -12.15Co- 13.9-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6965	Pratt & Whitney	Ni-58.05Cr -12.16Co- 13.9-(+)	1850	Blank	Poly	120°	192	1.0	Excellent
6966	Pratt & Whitney	Ni-58.5Cr- 12.16Co- 13.9-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6967	Pratt & Whitney	Ni-58.53Cr -12.16Co- 13.9-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6968	Pratt & Whitney	Ni-58.34Cr -12.17Co- 13.9-(+)	1850	Blank	Poly	120°	196	1.0	Excellent
6969	Pratt & Whitney	Ni-58.34Cr -12.17Co- 13.9-(+)	1850	Blank	Poly	120°	197	1.0	Excellent
6970	Pratt & Whitney	Ni-58.2Cr -12.14Co- 13.90-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6971	Pratt & Whitney	Ni-57.99Cr -12.10Co- 13.85-(+)	1850	Blank	Poly	120°	194	1.0	Excellent
6972	Pratt & Whitney	Ni-72.76Cr -12.4-(+)	2000	6:1	0010	60°	97	1.5	Good
6973	Pratt & Whitney	Ni-72.76Cr -12.4-(+)	2000	6:1	0010	60°	100	1.4	Good
6974	Pratt & Whitney	Ni-63.76Cr 12.4Co- 9.0-(+)	2000	6:1	0010	60°	97	1.4	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. ^{o}F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6975	Pratt & Whitney	Ni-63.76Cr 12.4Co- 9.0-(+)	2000	6:1	0010	60°	96	1.4	Good
6976	Pratt & Whitney	Ni-50.26Cr -12.4Co- 22.5-(+)	2000	6:1	0010	60°	97	1.4	Good
6977	Pratt & Whitney	Ni-50.26Cr -12.4Co- 22.5-(+)	2000	6:1	0010	60°	81	1.5	Good
6978	Pratt & Whitney	Ni-55.00Cr -12.4Co- 18.0-(+)	2000	6:1	0010	60°	92	1.4	Good
6979	Pratt & Whitney	Ni-55.00Cr -12.4Co- 18.0-(+)	2000	6:1	0010	60°	92	1.4	Good
6980	Pratt & Whitney	Ni-64.09Cr -12.4Co- 9.0-(+)	2000	6:1	0010	60°	97	1.4	Good
6981	Pratt & Whitney	Ni-64.09Cr -12.4Co- 9.0-(+)	2000	6:1	0010	60°	100	1.4	Good
6982	Pratt & Whitney	Ni-53.34Cr -12.4Co- 18.0-(+)	2000	6:1	0010	60°	86	1.4	Good
6983	Pratt & Whitney	Ni-53.34Cr 12.4Co- 18.0-(+)	2000	6:1	0010	60°	86	1.5	Good
6984	Pratt & Whitney	Ni-60.62Cr -12.4Co- 9.0-(+)	2000	6:1	0010	60°	92	1.3	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6985	Pratt & Whitney	Ni-60.62Cr 12.4Co- 9.0-(+)	2000	6:1	0010	60°	96	1.3	Good
6986	Pratt & Whitney	Ni-62.34Cr -12.4Co- 9.0-(+)	2000	6:1	0010	60°	92	1.4	Good
6987	Pratt & Whitney	Ni-62.34Cr -12.4Co- 9.0-(+)	2000	6:1	0010	60°	97	1.3	Good
6988	Pratt & Whitney	Ni-57.99Cr 12.15Co- 13.90-(+)	2000	6:1	0010	60°	108	1.2	Good
6989	Pratt & Whitney	Ni-58.05Cr -12.16Co- 13.92-(+)	2000	6:1	0010	60°	103	1.2	Good
6990	Pratt & Whitney	Ni-58.53Cr- 12.16Co- 13.92-(+)	2000	6:1	0010	60°	97	1.2	Good
6991	Pratt & Whitney	Ni-58.53Cr -12.16Co- 13.92-(+)	2000	6:1	0010	60°	107	1.1	Good
6992	Pratt & Whitney	Ni-58.34Cr 12.17Co- 13.93-(+)	2000	6:1	0010	60°	92	1.3	Good
6993	Pratt & Whitney	Ni-58.34Cr -12.17Co- 13.93-(+)	2000	6:1	0010	60°	92	1.3	Good
6994	Pratt & Whitney	Ni-58.2Cr- 12.14Co- 13.90-(+)	2000	6:1	0010	60°	89	1.2	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{e_x} (ips)	Surface
6995	Pratt & Whitney	Ni-57.99Cr -12.10Co- 13.85-(+)	2000	6:1	0010	60°	86	1.3	Good
6998	Pratt & Whitney	MARM-200	2150	43:1	7052	120°	162	.5	Good
6999	Pratt & Whitney	AF2-1DA	2150	43:1	7052	120°	165	.5	Good
7000	Pratt & Whitney	MARM-247	2200	43:1	7052	120°	140	.5	Good
7001	Pratt & Whitney	Monoloy 444	2250	43:1	7052	120°	151	.6	Good
7002	Pratt & Whitney	MARM-200	2250	20:1	7052	60°	124	1.4	Good
7003	Pratt & Whitney	AF2-1DA	2250	43:1	7052	120°	154	1.3	Good
7004	Pratt & Whitney	Ni-18Mo-8Al	2300	43:1	7052	120°	140	1.4	Good
7005	Pratt & Whitney	Ni-21Mo-8Al	2300	43:1	7052	120°	138	1.3	Good
7006	Pratt & Whitney	Ni-9Cr-8Al- 9W-.2C	2300	43:1	7052	120°	136	1.4	Good
7007	Sherritt-Gordon	Ni-16Cr- 4.5Al- 0.5Y_2O_3	1832	10:1	Poly	90°R	116	1.3	Good
7008	Sherritt-Gordon	Ni-16Cr- 4.5Al- 0.5Y_2O_3	1832	10:1	Poly	90°R	117	1.3	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
7009	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1832	12.5:1	Poly	90°R	140	1.1	Good
7010	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1832	12.5:1	Poly	90°R	146	1.1	Good
7011	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1922	10:1	Poly	90°R	116	1.3	Good
7012	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1922	10:1	Poly	90°R	116	1.2	Good
7013	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1922	12.5:1	Poly	90°R	136	1.2	Good
7014	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1922	12.5:1	Poly	90°R	138	1.2	Good
7015	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	1922	12.5:1	Poly	90°R	132	1.3	Good
7016	Sherritt-Gordon	Ni-16Cr-5Al-2ThO_2	1922	12.5:1	Poly	90°R	143	1.1	Good
7017	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	2012	10:1	Poly	90°R	103	1.4	Good
7018	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	2012	10:1	Poly	90°R	108	1.3	Good
7019	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	2012	12.5:1	Poly	90°R	124	1.3	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
7020	Sherritt-Gordon	Ni-16Cr-4.5Al-0.5Y_2O_3	2012	12.5:1	Poly	90°R	124	1.3	Good
7054	Pratt & Whitney	AF2-1DA Mod.	2250	43:1	7052	120°	130	1.1	Good
7055	Pratt & Whitney	AF2-1DA Mod.	2250	43:1	7052	120°	130	1.2	Good
7056	Pratt & Whitney	Ni-18Mo-6Al	2250	20:1	7052	120°	119	1.2	Good
7057	Pratt & Whitney	Ni-16Cr-4Al-15Cb	2250	43:1	7052	120°	151	.7	Good
7058	Pratt & Whitney	Ni-14Mo-6Al-6Ta	2300	43:1	7052	120°	162	.8	Good
7059	Pratt & Whitney	Ni-15Mo-7Al-3Ta	2300	43:1	7052	120°	162	.7	Good
7060	Pratt & Whitney	Ni-18Mo-7Al-3Ta	2300	43:1	7052	120°	151	.9	Good
7061	Pratt & Whitney	Ni-6Cr-2.5 Al-20Cb	2300	43:1	7052	120°	----	----	----
7062	Pratt & Whitney	Ni-Cr-Al+Tac	2300	43:1	7052	120°	135	1.1	Good
7063	Pratt & Whitney	Ni-Tac-Low-C	2300	43:1	7052	120°	127	1.2	Good
7064	Pratt & Whitney	Ni-6Cr-6Al-10Cb	2300	43:1	7052	120°	108	1.2	Good
7065	Pratt & Whitney	Ni-13Cb-8Al	2300	43:1	7052	120°	119	1.1	Good

APPLIED METAL PROCESSING

NICKEL BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	Ve_x (ips)	Surface
7066	Pratt & Whitney	Ni-18Mo-8Al	2300	43:1	7052	120°	140	1.0	Good
7067	Pratt & Whitney	Ni-18Mo-8Al+Zr	2360	43:1	7052	120°	130	1.2	Good

APPLIED METAL PROCESSING

IRON BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6938	Pratt & Whitney	Mild Steel	1600	8:1	0010	120°	163	1.3	Good
6939	Pratt & Whitney	Mild Steel	1600	8:1	0010	120°	154	1.4	Good
6940	Pratt & Whitney	Mild Steel	1600	8:1	0010	120°	161	1.4	Good
6941	Pratt & Whitney	Mild Steel	1600	8:1	0010	120°	155	1.4	Good
6942	Pratt & Whitney	Mild Steel	1600	8:1	0010	120°	154	1.4	Good
6943	Pratt & Whitney	Mild Steel	1600	8:1	0010	120°	157	1.4	Good
6996	Pratt & Whitney	Fe-9Ni-4Co-2C	1500	12:1	8871	60°	134	1.5	Good
6997	Pratt & Whitney	Fe-9Ni-4Co-2C	1400	12:1	8871	60°	144	1.3	Good
7021	Pratt & Whitney	Mild Steel	1600	8:1	0010	90°	153	1.4	Good
7022	Pratt & Whitney	Mild Steel	1600	7.8:1	0010	90°	167	1.4	Good
7023	Pratt & Whitney	Mild Steel	1600	7.8:1	0010	90°	157	1.4	Good
7024	Pratt & Whitney	Mild Steel	1600	7.8:1	0010	90°	165	1.4	Good
7025	Pratt & Whitney	Mild Steel	1600	7.8:1	0010	90°	170	1.4	Good
7026	Pratt & Whitney	Mild Steel	1600	7.8:1	0010	90°	171	1.4	Good

APPLIED METAL PROCESSING

COBALT BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{e_x} (ips)	Surface
6758	Polymet	Co-18Cr-5Mo-2B	1750	16:1	Poly	90°	113	2.0	Good
6759	Polymet	Co-20W-28Cr	2000	9:1	Poly	90°	100	2.0	Good
6760	Polymet	Co-20W-28Cr	2000	9:1	Poly	90°	103	2.0	Good
6863	Polymet	Co-Base	2000	16:1	Poly	90°	97	2.1	Good
6871	Polymet	Co-Base	2000	9:1	Poly	90°	73	2.5	Good
6877	Pratt & Whitney	Co-Tac 741	2200	43.73:1	7052	120°	132	0.5	Good
6878	Pratt & Whitney	Co-Tac 741	2200	43:1	7052	120°	142	----	Good
6905	Polymet	Co-30Cr-W/o-20W	2000	16.3:1	Poly	90°	151	1.7	Good
6906	Polymet	Co-30Cr-W/o-20W	2000	8.9:1	Poly	90°	143	1.9	Good
6907	Polymet	Co-30Cr-W/o-20W	2200	8.9:1	Poly	90°	143	2.0	Good
6908	Polymet	Co-30Cr-20W	2000	16.34:1	Poly	90°	167	2.0	Good

APPLIED METAL PROCESSING

ALUMINUM BASE

Extrusion Number	Agency	Alloy	Temp. ^{o}F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6789	AFML/LLM-1	17 Al Powder	2575	---	7740	90^o	43	1.5	Good
6835	AFML/LLM	7075-Al	900	10:1	Poly	90^o	157	.8	Good
6865	Pratt & Whitney	7057-Al Alloy	850	Blank	Poly	90^o	----	.5	Good

APPLIED METAL PROCESSING

COPPER BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6834	AFML/LLM	Cu.	900	10:1	Poly	90°	146	1.0	Good
6869	AFML/LLM	Cu.	900	10:1	Poly	90°	148	1.1	Good
6870	AFML/LLM	Cu.	900	10:1	Poly	90°	159	1.1	Good

APPLIED METAL PROCESSING

TANTALUM BASE

Extrusion Number	Agency	Alloy	Temp. °F	Red. Ratio	Billet Lube	Die Angle	P_t (ksi)	V_{ex} (ips)	Surface
6771	University of Calif.	Ta-20Hf	3000	2.5:1	Bare	60°	97	4.5	Excellent

☆U.S.Government Printing Office: 1978 — 757-080/50